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Although all targets were visible through the devices when observers were shown when and where to look, almost no target recognition occurred when any of the aids were used in a search viewing-mode under the conditions of the study.

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Three hand-held image intensifiers were studied. Two of these were passive visual aids (Starlight Scope and Uniscope) and one was an active IR viewer (Find-R-Scope). These devices were evaluated in terms of number of targets (trucks, boats, village) recognized on a 1000:1 scale terrain model. Simulated air-to-ground views of 20 observers were provided as they circled the model at a simulated 520 MPH and 8500 ft slant range under a moonlight illumination level.

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FOREWORD

The research reported in this paper was conducted by personnel of the Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

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INTRODUCTION

In view of the many critical and diversified requirements for the visual acquisition of targets under dark or near-dark conditions, there has been a continuing forward thrust in electro-optical technology to overcome man's visual limitations at night.

Ideally there is a need for image-intensification devices with sufficient light amplification, resolution and field of view to provide an equivalent night time capability for visual acuity, as exists during the day. Rosell (Ref. 5) has demonstrated the feasibility of such a possibility and Biberman et al (Ref. 1) also provides a basis for optimism in the review and evaluation of current technological advances. However, despite greater engineering sophistication in the design of image intensification devices, there have been relatively few validating behavioral studies which provide visual performance measures of target acquisition obtained under operational conditions.

One class of image intensification device is the hand-held monocular viewer. A well known instrument of this type with many years of operational use is the Army-developed Starlight Scope. Among the improved versions of the Starlight Scope is the Uniscope, another hand-held device recently developed for the Air Force. An alternative technique used in night-vision devices is one which actively employs an invisible source of IR illumination so the observer does not have to depend on residual natural light. A relatively inexpensive and commercially available device of this type is the Find-R-Scope built by FJW Industries.

Only a few controlled behavioral tests of target acquisition using hand-held image-intensifier aids have been performed. In one of these, a ground-to-ground test on search effectiveness with four passive night vision devices (including the Starlight Scope) was run on 123 observers [Sternberg and Banks (Ref. 6)]. Field testing was conducted under starlight, half-moon illumination conditions. Although the percentage of targets detected under the best viewing conditions was as high as 75%, this measure was shown to be severely reduced by such factors as ambient light, viewing range, target type, target-background contrast, and operator search techniques.

No comparable published research findings on air-to-ground performance tests appear to

exist. In an unpublished study [Porterfield (Ref. 4)] visual responses of four airborne observers were measured using unaided vision, binoculars or the Starlight Scope. Both visual acuity markers and trucks were used as targets and either slant range to detection or angular resolution was used as a measure of acquisition. Ambient brightness varied from 10^3 ft candles (representing sunlight) to 10^{-4} ft candles (representing starlight). Target acquisition at low brightness levels was well-demonstrated for all subjects using the Starlight Scope. Correct responses were made even for low-contrast targets at the lowest illumination level, though in this the slant range to detection was limited to about 1000 ft.

The present exploratory study, utilized a 1000:1 scale circular terrain model with associated simulation techniques, and was designed to compare air-to-ground target acquisition performance at a low-light level using the three previously mentioned devices (Starlight Scope, Uniscope and Find-R-Scope). Comparison was also made against performance of the unaided eye. One purpose of the test was to evaluate possible technological advantages designed into the two more recently developed aids (Uniscope and Find-R-Scope). The test was also designed to provide a rather severe feasibility test of the devices under marginal viewing conditions. Data were taken at a relatively high airspeed (520 MPH), long slant range (8500 ft) and low (.003 to .009 ft candles) illumination level. It was reasonable to assume that, if acceptable performance of the instruments could be demonstrated with these constraints, then one could confidently recommend their useful applications under a wide range of less stringent operational conditions.

METHOD

Image Intensification Devices

The three night-vision devices tested were all monocular electro-optical instruments designed for manual use. Two of these, the Starlight Scope and Uniscope, represent passive techniques which use available night skylight for target illumination, while the Find-R-Scope is an active infrared viewer operating in the near IR range (400 to 1200 nanometers). For purposes of experimental comparison, the Starlight Scope represents a standard Armed Forces instrument of well-established operational use. The Uniscope was selected as typical of a more advanced device designed to provide the following kinds of improvements: (a) high adjustable brightness gain and low noise; (b) freedom from "blooming"; (c) low persistence; and (d) low distortion. The Find-R-Scope, in addition to its active IR feature, represents an inexpensive, lightweight, commercially available device with a relatively large field of view. Descriptive data characterizing the three viewers are given in Table 1.

Terrain Model and Targets

The tactical targets to be visually acquired were realistically positioned on a circular terrain model. Both targets and terrain were constructed at a scale factor of 1:1000. An illustration of the model, showing the location of the five targets, appears in Figure 1. As can be seen, the model contains a simulated bay, desert, and foliated areas. The central elevated portion (containing two land-locked lakes) rises to a high point, 1.5 ft above the bay level. Figure 1, also shows the location of the targets, arrayed in counter clockwise order.

The target-designating symbols are defined as follows:

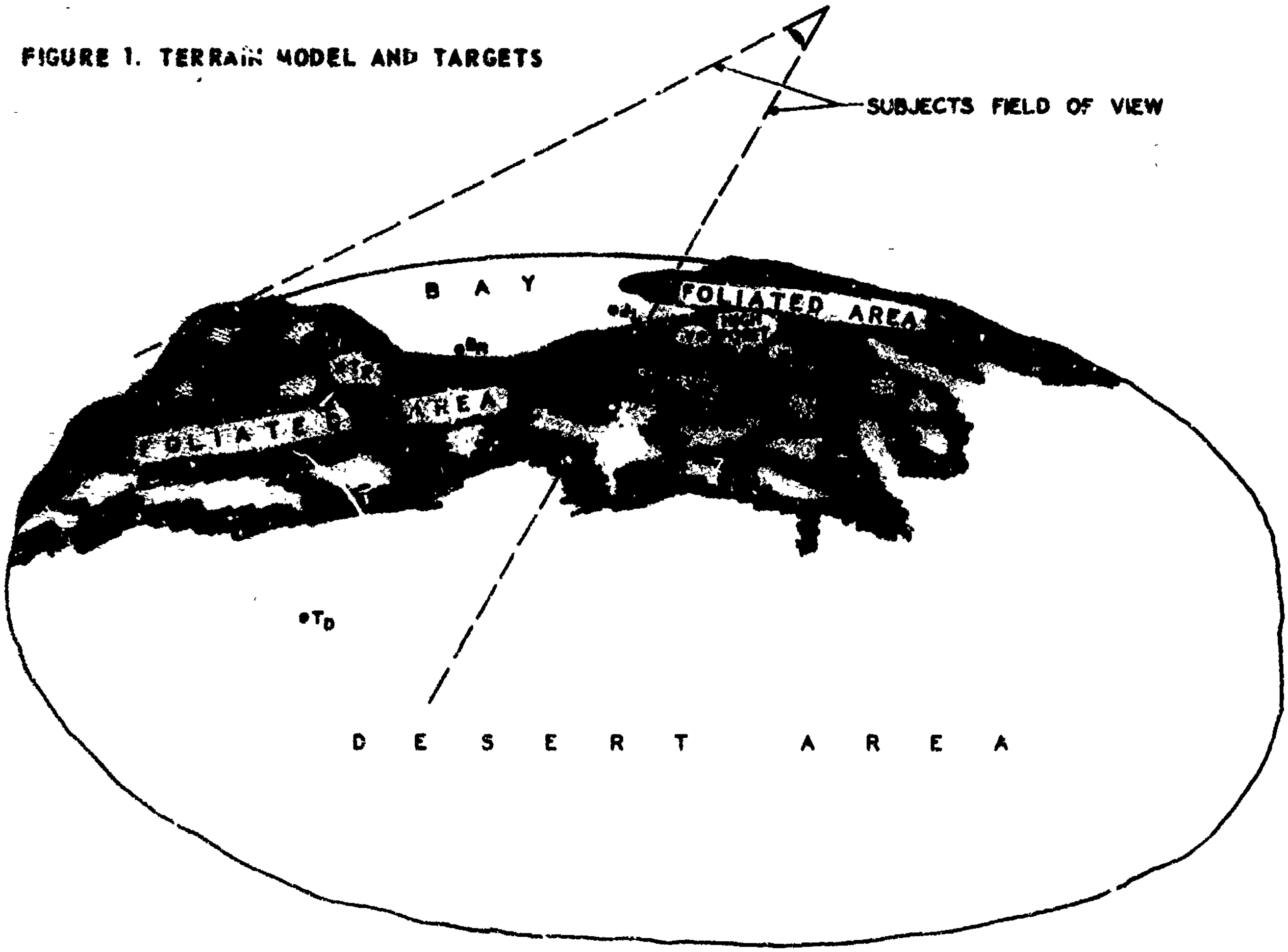
- V - Small village near central bay shore.
- B_L - Twenty ft boat on the bay to the left in the FOV.
- B_R - Twenty ft boat on the bay to the right in the FOV.
- T_F - Two and one-half ton olive-drab truck parked in foliage.
- T_D - Two and one-half ton olive-drab truck parked in the desert area.

The model rested on a motorized turn-table which could be rotated at a constant speed.

Illumination

The only illumination in the otherwise light-tight experimental room was a source of simulated moonlight used in a previous experiment [MacLeod and Hilgendorf (Ref. 3)]. This was provided by four 1816 GE lamps housed in a modified altimeter casing and mounted to an overhead steel beam which revolved at the same rate as the model. From here it was suspended six ft above the edge of the model and pointed toward the center of the terrain at a 45° angle. The luminous intensity of the source was .4 candles. Terrain illumination over areas containing targets ranged from .003 to .009 ft candles. These values represent ambient levels between one-half and full moonlight [Sternberg and Banks (Ref. 6)].

FIGURE 1. TERRAIN MODEL AND TARGETS



Subjects

The subjects were twenty male college students, visually screened by the Ortho-Rater visual acuity test and the Dvorine Pseudoisochromatic Color Vision test. They were also given brief preparatory training with duplicates of the experimental targets viewed under normal room illumination on a small rectangular terrain board. Here the subject was required to familiarize himself with the targets by repeatedly observing and designating them to the experimenter.

Experimental Procedure

Each subject was given one trial seated in the position shown in Figure 1. The Uniscope was set at maximum gain and proper-focal settings for the eye piece and objective lens of all scopes were preselected. Each device was mounted on a tripod and positioned so that the objective lens was 2.5 ft above sea level of the model and centered at a mid-radial point on the right of the model perpendicular to the observer's line of sight. Under these conditions the simulated observer-altitude

TABLE 1: COMPARATIVE DATA ON THE THREE NIGHT VISION AIDS

	STARLIGHT SCOPE	UNISCOPE	FIND-R-SCOPE
Type of Illumination	Passive Visual	Passive Visual	Active IR
Weight (lbs)	7	7	1.4
Magnification Factor	4	6	1.1
Field of View (degrees)	10	10	33

TABLE 2: EXPERIMENTAL AND SIMULATED VISUAL/FLIGHT PARAMETERS

	Experimental	Simulated
Air Speed	.763 ft/sec	520 MPH
Altitude	1.5 ft	1500 ft
Radius of Aircraft Turn	8.5 ft	8500 ft
Radial Distance on Model to Center of FOV	2.5 ft	2500 ft
Radial width of FOV		
Starlight Scope	1.6 ft	1600 ft
Uniscope	1.6 ft	1600 ft
Find-R-Scope	5.4 ft	5400 ft
Slant Range to Center of FOV	8.5 ft	8500 ft
Speed of Target at Center of FOV Relative to Observer	.224 ft/sec	152 MPH

TABLE 3: SUMMARY OF RESULTS SHOWING NUMBER OF TARGETS FOUND, MEAN RESPONSE TIMES AND ERRORS

VIEWING CONDITION	N. TARGETS FOUND	MEAN RT*	ERRORS
Unaided Eye	0	70.0	3
Starlight Scope	0	70.0	3
Uniscope	3	66.8	2
Find-R-Scope	1	68.4	7

* A response time of 70 sec (Trial Duration) is assigned whenever a target is not found.

TABLE 4: SUMMARY OF ANALYSIS OF VARIANCE FOR ERRORS

SOURCE	SS	DF	MS	F	P
Total	15.48	99	-	-	
Between S's	4.28	19	-	-	
View. Cond.	1.32	3	.44	2.37	NS
$Error_b$	2.96	16	.185	-	
Within S's	11.20	80	-	-	
Targets	.93	4	.23	1.5	NS
Tgts x View. Cond.	.83	12	.069	<1	NS
$Error_w$	9.44	64	.148	-	

was 2500 ft and the simulated slant range (to the center of the field of view) was 8500 ft. Since both the Starlight and Uniscope have a FOV of about 10°, the width of terrain visible through these devices was about 1.5 ft. In the case of the Find-R-Scope with a larger FOV (33°) the width of view was about five ft. For trials with unaided vision, the position of the subject's dominant eye was fixed by means of a head-and-chin rest so that his line and center of regard on the terrain was equivalent to the other conditions. Although in this case the field of view was relatively large, visual acquisition was still confined to the right hemisphere of the terrain model. Monocular vision was maintained under all viewing conditions by covering the non-dominant eye. After the subject was seated with his eye and/or viewer in the proper position, he was dark-adapted for eight minutes before the simulated moonlight was turned on. At the same time rotation of the model was initiated at the rate of about nine degrees per second and the trial was under way. During the 70-second period of rotation, the subject was instructed to name all recognizable targets entering his field of view. The order of entry was as follows: V, B_L, B_R, T_F, and T_D.

Three types of performance data were recorded on each trial: (a) Response time for all correct target recognition responses (measured from the start of his trial to each correct response). For all failures to respond, the 70-second duration of the trial interval was arbitrarily assigned as the response time; (b) Targets found (the number of targets correctly recognized and located); and (c) Errors (the number of responses involving confusion of targets with non-targets).

Table 2 summarizes both experimental and simulated test parameters. The first column lists those parameters comprising actual conditions of the experiment, while the second column expresses the same data in terms of simulated in-flight conditions during a single banking turn.

Experimental Design

The twenty subjects were equally divided into four groups each of which comprised one of the experimental viewing conditions. The experimental design appropriate for the three types of performance measures was a 4 x 5 factorial with repeated measures on the second factor. The first factor refers to viewing condition and the second factor to target type.

Results

The results are summarized in Table 3 which shows for each of the viewing conditions: (a) the total number of targets found; (b) the mean response time (RT) per target; and (c) the total number of errors.

It is immediately apparent from this data that there is almost no evidence of target acquisition under any of the experimental conditions. Even in the best case (with the Uniscope) only three correct target recognitions occurred out of 25 experimental opportunities. Thus, under the conditions of this experiment, one finds no sign of target acquisition using the unaided eye and very little indication of improving this situation with any of the night vision aids.

Table 3 does show a substantial number of errors occurring under each viewing condition where the subject confuses non-targets (e.g., trees) with the targets he is anticipating. A two-way analysis of variance was performed to determine possible effects of viewing conditions or targets on the occurrence of such errors. Table 4 summarizes the results of this analysis. No significant main effect or interaction is indicated.

DISCUSSION

In attempting to explain the negative findings of the present study, one must consider a number of constraining factors which were designed into the experiment and which probably diminished the visual effectiveness of the image intensifiers. These factors include: aircraft speed, terrain illumination and slant range. Of these aircraft speed (although relatively high) may have been the least critical since the rate of target movement across the observer's FOV (for targets located 2.5 ft from the center of the turn-circle) is less than one-third of his actual air speed. Slant range on the other hand, appears to have been unacceptably large. The longest viewing distances reported in the two previously mentioned studies by Sternberg and Banks and Porterfield were respectively about 3600 and 3300 feet; and, even at these values, there was little indication that tactical targets could be recognized at a half-moonlight level of illumination through a Starlight Scope. Sternberg and Banks found a strong interaction between viewing distance and ambient illumination wherein the percentage of targets detected at a given distance (up to 3600 ft) is more than doubled as the illumination level increases from starlight to full moonlight.

At the 5500 ft viewing distance in the present study the maximum visual subtense of the targets with the unaided eye is about 13 minutes. With a 4x magnification factor of the Starlight Scope this value would be increased to 52 minutes. This is approximately the value given [Blackwell (Ref. 2)] for minimum perceptibility of a circular target viewed under similar conditions (.001 ft candles illumination and .1 target-to-background contrast). It would appear therefore that the obtained visual subtense may have been adequate for target detection if the observer knew what he was looking for and where to look.

This supposition was, in fact, confirmed during some qualitative pilot observations where several observers were able to discern all of the targets through the scopes when the objects were placed in the center of the field of view and the terrain model was not moving.

The inability of subjects to recognize targets under the experimental conditions, therefore appears to be explained by the requirements for free search wherein the observer has no specific frame of reference for the location of the targets. It appears likely that effective use of the night-vision scopes for this kind of search task will require some combination of larger targets sizes, shorter range, higher brightness contrast or higher levels of illuminations. Such a search factor is also stressed by Sternberg and Banks who show (under more favorable viewing conditions) that about 50% of the targets which are visible when pointed out were not found during search.

An in-flight validation which duplicates the parameters of the terrain model study is currently being planned as a check on the negative results. Additional research with the terrain model is also obviously required to evaluate a wider variety of recently developed image intensifier aids. These tests should be designed to reveal both optimal and limiting conditions for using each aid in visual target acquisition.

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